Annals of Clinical and Analytical Medicine
*Original Research*

# Subscapularis volume analysis as a radiological criterion for evaluating success after arthroscopic repair of supraspinatus tears

Evaluation of isolated supraspinatus tears repair by subsacapualaris volume analysis

Kerim Öner[1], Muhammet Salih Ayas[2], Mehtap Oktay[3]
[1] Department of Orthopedics and Traumatology, Bozok University, Yozgat
[2] Department of Orthopedics and Traumatology, Region Research and Education Hospital, Erzurum
[3] Department of Radiology, Sorgun State Hospital, Yozgat, Turkey

**Abstract**

Aim: The aim of this study was to compare the volumes of the supraspinatus and subscapularis muscles measured on preoperative magnetic resonance imaging (MRI) with the volumes obtained at the end of the postoperative 1st year, and to examine whether the change in the intact subscapularis muscle volumes is an indicator of well-being.

Materials and Methods: The study included twenty-one patients who underwent double-row arthroscopic repair for full-thickness isolated supraspinatus rotator cuff tear and who were followed-up in our hospital between 2016 and 2019. All patients underwent clinical and radiological MRI examinations of the shoulder before arthroscopic repair and at the final follow-up 1 year after surgical repair. Fatty degeneration of the supraspinatus muscles was graded according to the Goutallier classification. Functional results were evaluated with the Constant shoulder score. For muscle volume measurements, sagittal oblique PD-weighted images were used. The supraspinatus (SPS) and subscapularis (SS) muscle areas were measured in the Y-shape formed by the coracoid process, spina scapula, and scapula body in the suprascapular groove.

Results: The mean age was 57.33 ± 8.27 (range, 42 to 69) years. Among the patients, 57.1% (n = 12) were female and 42.9% (n = 9) were male. The mean follow-up time was 22.57 ± 7.87 (range, 12 to 36) months. The degrees of fatty degeneration according to the Goutallier classification were as follows: 7 patients (33%) had grade 1 atrophy, 10 patients (47.6%) had grade 2 atrophy and 4 patients (19%) had grade 3 atrophy. The Constant score increased from 48.38 ± 5.57 to 81.14 ± 6.11 ($p<0.001$). On the final MRI examination, the supraspinatus muscle volume increased from a mean value of 462.48 ± 135.68 to a mean value of 480.81 ± 140.83 ($p =0,004$). The mean subscapularis muscle volume increased from 1374.29 ± 248.21 to 1415.71 ± 250.56 ($p<0.001$). A positive correlation was found between the postoperative subscapularis volume and postoperative supraspinatus volume values of the patients ($p = 0.004$; $r = 0.601$).

Discussion: The postoperative volume values of all patients increased in the follow-up after isolated supraspinatus tears. In the patients with grade 1 and 2 fatty degeneration, the volume increase in the supraspinatus and subscapularis muscles after repair was significant and correlated with each other. We think that the use of subscapularis muscle volume in radiological assessment of well-being following the repair of the rotator cuff may be a criterion for evaluation of success.

**Keywords**

Rotator cuff; Supraspinatus muscle, Subscapularis muscle; MRI; Volume analysis

DOI: 10.4328/ACAM.20278 Received: 2020-07-12 Accepted: 2020-08-17 Published Online:2020-08-20 Printed: 2021-03-01 Ann Clin Anal Med 2021;12(3):302-307

Corresponding Author: Muhammet Salih Ayas, Department of Orthopedics and Traumatology, Region Research and Education Hospital, Erzurum, Turkey.
E-mail: muhammetsalihayas@yahoo.com.tr P: +90 532 656 10 88
Corresponding Author ORCID ID: https://orcid.org/0000-0002-7427-2223

## Introduction

Rotator cuff tear is a common injury that causes pain and functional disability. Arthroscopic surgical repair is a widely accepted treatment for full-thickness rotator cuff tears, and excellent clinical results have been reported [1]. Treatment results are usually evaluated by pain, range of motion, and clinical scorings [2].

MRI detects rotator cuff tears with high sensitivity and specificity. Because of this feature, MRI has become a routinely used method for the preoperative and postoperative evaluation of patients with rotator cuff dysfunctions [3]. In recent years, researchers have started to attach importance to radiological evaluation as well as clinical evaluation in order to make better conclusions after rotator cuff repair. These evaluations have mostly focused on fatty infiltration and atrophy in the supraspinatus muscle [4-6] .

As atrophy develops in the relevant muscle after rotator cuff tears, it is natural to have an increase in the volume of an atrophic muscle after rotator cuff repair [7,8]. If radiological measurements are performed only for the repaired muscle tissue, positive results are likely. In this case, it may not radiologically reflect the actual success. There is currently no definite and reliable method for preoperative and postoperative quantitative evaluation of rotator cuff muscle volumes [9, 10]. However, a reliable parameter is important for estimating the results after rotator cuff repair. Based on this, we thought that the volume change in the subscapularis muscle, which has a different insertion site from other components of the rotator cuff, might be a better indicator [11].

In order to make better conclusions, we examined a group of patients who had isolated supraspinatus muscle tear. The aim of this study was to compare the volumes of the supraspinatus and subscapularis muscles measured on preoperative magnetic resonance images (MRI) with the volumes on MRI obtained at least at the end of the first postoperative year. We also aimed to examine whether the change in the volumes of the intact subscapularis muscle was indicative of well-being of the rotator cuff muscles.

## Material and Methods

Twenty-one patients with chronic-degenerative rotator cuff tears who underwent double-row arthroscopic rotator cuff repair in our hospital between March 2016 and April 2019 were retrospectively analyzed. Informed consent form was obtained from each patient. The study protocol was approved by the Clinical Research Ethics Committee of Bozok University (2017 –KAEK-189-2020.06.10-06).

### *Inclusion and Exclusion Criteria*

Patients, whose MRI was performed in our hospital one week before the operation, who had a follow-up MRI at least at the end of the first postoperative year, who had a successful rotator cuff repair, who had small and medium-size full-thickness tear in the rotator cuff according to the DeOrio classification [12] on preoperative MRI, and who were considered grade 1-2-3 according to the Goutallier classification system on preoperative MRI, were included in the study [13].

Patients, who did not have preoperative and postoperative MRI performed in our hospital, who had isolated subscapularis tear, who had SLAP tear that required surgical intervention, who had bankart lesion, who had a previous history of surgery in the same shoulder, and whose data could not be reached, were excluded from the study.

### *Surgical Procedures and Rehabilitation*

All surgical procedures were performed using the standard arthroscopic portals with the patient placed in the beach chair position. Subacromial decompression and acromioplasty were performed on all patients to create a smooth acromion. During the surgery, rotator cuff tears were re-measured and the size of the tear measured by MRI was confirmed. No further surgical intervention was performed. In order to obtain better quality tendon tissues, the torn rotator cuff tip was debrided. For osteointegration of the rotator cuff tendons, spongy bone bed at the rotator cuff insertion site was prepared with the help of a burr. If the supraspinatus tendon's mobility was not sufficient for repair, the release was performed to mobilize the tendon. All patients underwent arthroscopic double-row repair.

After rotator cuff repair, they were immobilized with a Velpeau brace. Velpeau braces were used for 6 weeks in all patients. All patients underwent the same rehabilitation program. On the first postoperative day, passive shoulder movements, active elbow and hand movements were started under the supervision of a physiotherapist. After the brace was removed, active ROM exercise for the supraspinatus muscle and range of motion was started under the supervision of a physiotherapist, and the patients were allowed to use their arms in daily activities. This treatment protocol continued until the 12th week. At the end of the 6th month, sports activities and heavy works were allowed. The rehabilitation protocol was carried out with regular follow-up under the supervision of a physiotherapist.

### *Clinical and radiological evaluation*

Preoperative and postoperative clinical evaluation of all patients was made according to the Constant score [1]. Clinical scoring was categorized as follows: excellent, 90 to 100; good, 80 to 89; moderate, 70 to 79; or poor, 69 or lower.

Preoperative and postoperative (at the end of the first year) radiological evaluations were performed in the same center with shoulder MRI in all patients. A GE Signa Explorer 1.5 Tesla (General Electric Medical Systems, Waukesha, WI, USA) device was used for scans. All patients were placed in the supine position and the shoulder was placed in a slightly external rotation. A 16-channel coil was placed in the shoulder region and scans were performed. Our clinic's routine shoulder MRI protocols were followed for shoulder MRI scans. The sequences we used were as follows: axial proton density (PD) fat-suppressed (TR / TE (repetition time/ echo time ) 3178/52 ms, FOV (field of view) 20x20 cm, imaging matrix 256x256, cross-section space 0.5 mm, cross-section thickness 3.5 mm), coronal oblique PD fat-suppressed (TR / TE 3024/79 ms, FOV 16x16 cm, imaging matrix 224x224, cross section space 1, 0 mm, cross-section thickness 3.0 mm), coronal oblique T1-weighted (TR / TE 497/11 ms, FOV 16x16 cm, imaging matrix 288x192, cross-section space 1.0 mm, cross- section thickness 3.0 mm), sagittal oblique PD weighted sequences (TR / TE 3510/72 ms, FOV 16X16 cm imaging matrix 224x224, cross-section space 1.0 mm, cross-section thickness 3.0 mm). The images were then transferred to a workstation (Akgun PACS). The MRI was evaluated by an expert independent radiologist in the evaluation of the musculoskeletal system who was blinded to the clinical follow-up of the patients. The measurements were performed by the same radiologist using the PACS system. Sagittal oblique PD-weighted images were used for the measurements [14]. The supraspinatus (SPS) and subscapularis (SS) muscle areas were measured in the Y shape formed by the coracoid process, spina scapula, and scapular body in the suprascapular groove (Figure 1-2).

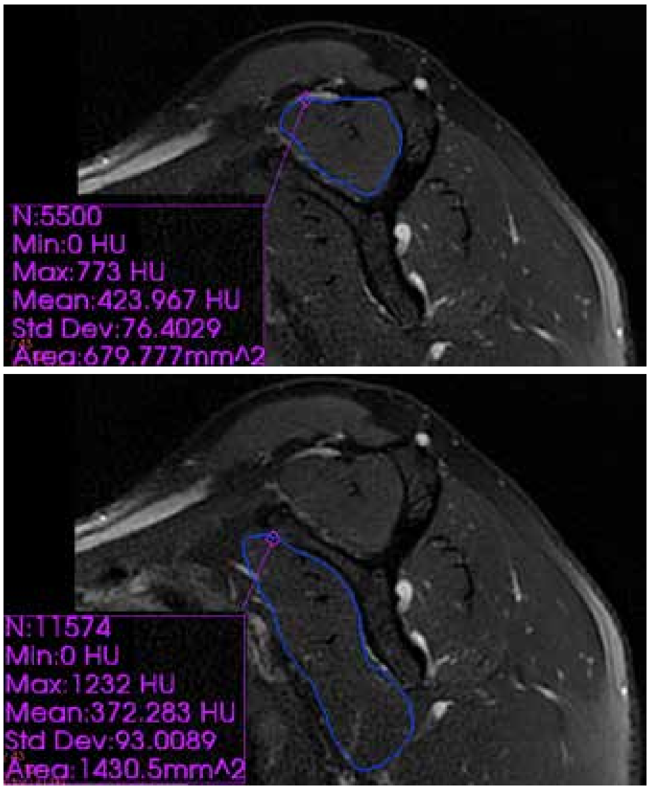


**Figure 1-2.** The supraspinatus (SPS) and subscapularis (SS) muscle areas were measured in the Y shape formed by the coracoid process, spina scapula, and scapular body in the suprascapular groove.

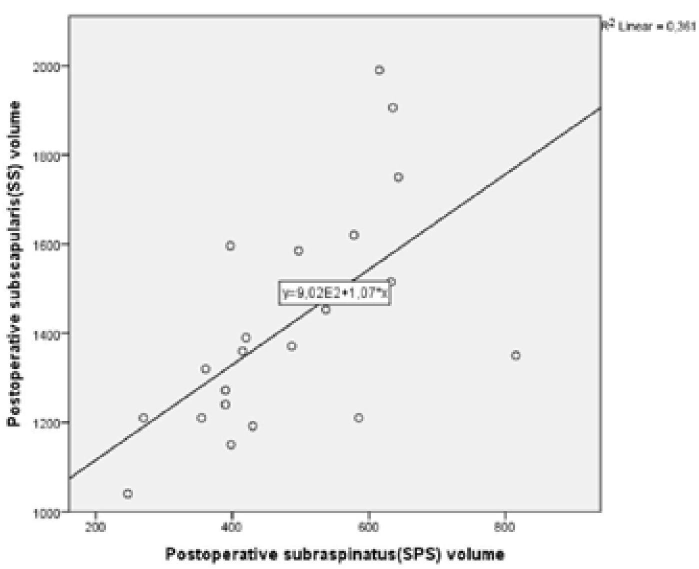


**Figure 3.** Correlation analysis of the postoperative subscapularis volume and postoperative supraspinatus volume values.

***Statistical Analysis***

While carrying out the statistics of the study, numerical data were given as mean and standard deviation, and the categorical data were given as numbers and percentages for the descriptive statistics. The distribution of numerical data was tested by histogram graphs. Repeated numerical data were analyzed with the Wilcoxon test. Pearson correlation analysis was used for correlations. A p-value of <0.05 was considered statistically significant. SPSS 23.0 software package was used for the analysis.

**Results**

The study included 21 patients who met the study criteria. The mean age of all patients was 57.33 ± 8.27 (range, 42 to 69) years. Among the patients, 57.1% (n = 12) were female and 42.9% (n = 9) were male. The repair side was the right side in 76.2% (n = 16) of the patients and the left side in 23.8% (n = 5). The dominant side of all patients was the right side (n = 16). The degrees of fatty degeneration according to the Goutallier classification were as follows: 7 patients (33%) had grade 1 atrophy, 10 patients (47.6%) had grade 2 atrophy and 4 patients (19%) had grade 3 atrophy. According to the DeOrio classification, 1 patient had small tear (<1 cm) and 20 patients had moderate tear (1-3 cm). Some descriptive data of the patients are given in Table 1.

The postoperative clinical and radiological results were evaluated in the first year. The patients' mean follow-up time was 22.57 ± 7.87 (range, 12 to 36) months. The preoperative Constant score was 48.38 ± 5.57 and the postoperative Constant score was 81.14 ± 6.11; the difference was statistically significant (p<0.001).

When the mean preoperative supraspinatus muscle volume (462,48±135.68) was compared with the mean postoperative muscle volume (480.81±140,83), the difference was statistically significant (p <0.004). When the preoperative subscapularis muscle volume (1374,29±248,21) was compared with the mean postoperative muscle volume (1415,71±250,56), the difference was statistically significant (p<0.001) (Table 2).

A correlation analysis was performed for the postoperative subscapularis volumes and postoperative supraspinatus volumes. There was a significant positive correlation between these values (p = 0.004; r = 0.601) (Figure 3).

The patients were divided into groups based on the Goutallier's fatty degeneration classification, and their data were analyzed separately. No significant difference was observed in the preoperative - postoperative supraspinatus volumes of the patients with grade 2 fatty degeneration. Apart from this, a significant increase was observed in the postoperative period in all other parameters of the patients with grade 1 and grade 2 fatty degeneration (p <0.05). In patients with grade 3 fatty degeneration, no significant change was observed in the preoperative and postoperative values (Table 3).

**Discussion**

In this study, we examined 21 patients who had isolated supraspinatus tear and grade 3 and lower grade fatty degeneration in order to make better conclusions after rotator cuff repair. In the clinical evaluation of the results,

**Table 1.** Descriptive data of patients

| Characteristic | | n | % |
|---|---|---|---|
| Sex | Male | 9 | 42,9 |
| | Female | 12 | 57,1 |
| Side | Right | 16 | 76,2 |
| | Left | 5 | 23,8 |
| Preoperative Goutallier Fatty Dejeneration Grade | 1. Grade | 7 | 33,3 |
| | 2. Grade | 10 | 47,6 |
| | 3. Grade | 4 | 19,0 |
| Preoperative DeOrio classification | Small | 1 | 4,8 |
| | Medium | 20 | 95,2 |

**Table 2.** Preoperative - postoperative radiological and clinical evaluation of the patients.

| | Mean | n | Std. Deviation | p |
|---|---|---|---|---|
| Preoperative Supraspinatus volume | 462,48 | 21 | 135,68 | 0,004 |
| Postoperative Supraspinatus volume | 480,81 | 21 | 140,83 | |
| Preoperative Subscapularis volume | 1374,29 | 21 | 248,21 | <0,001 |
| Postoperative Subscapularis volume | 1415,71 | 21 | 250,56 | |
| Preoperative Constant score | 48,38 | 21 | 5,57 | <0,001 |
| Postoperative Constant score | 81,14 | 21 | 6,11 | |

**Table 3.** Preoperative and postoperative volume analyses according to Goutallier fatty degeneration stages and representation of the constant score.

| Goutallier fatty Dejeneration Grade | | Mean | n | Std. Deviation | p |
|---|---|---|---|---|---|
| 1.Grade | Preoperative Supraspinatus volume | 460,57 | 7 | 143,57 | 0,042 |
| | Postoperative Supraspinatus volume | 478,57 | 7 | 142,01 | |
| | Preoperative Subscapularis volume | 1434,57 | 7 | 371,47 | 0,042 |
| | Postoperative Subscapularis volume | 1473,86 | 7 | 372,57 | |
| | Preoperative Constant score | 49,43 | 7 | 3,95 | 0,017 |
| | Postoperative Constant score | 82,00 | 7 | 3,83 | |
| 2.Grade | Preoperative Supraspinatus volume | 451,50 | 10 | 132,23 | 0,185 |
| | Postoperative Supraspinatus volume | 459,00 | 10 | 129,96 | |
| | Preoperative Subscapularis volume | 1348,00 | 10 | 169,91 | 0,009 |
| | Postoperative Subscapularis volume | 1392,60 | 10 | 184,86 | |
| | Preoperative Constant score | 50,80 | 10 | 4,44 | 0,005 |
| | Postoperative Constant score | 83,40 | 10 | 6,39 | |
| 3.Grade | Preoperative Supraspinatus volume | 493,25 | 4 | 165,48 | 0,068 |
| | Postoperative Supraspinatus volume | 539,25 | 4 | 187,25 | |
| | Preoperatif Subscapularis volume | 1334,50 | 4 | 187,74 | 0,144 |
| | Postoperative Subscapularis volume | 1371,75 | 4 | 161,65 | |
| | Preoperative Constant score | 40,50 | 4 | 3,41 | 0,059 |
| | Postoperative Constant score | 74,00 | 4 | 3,26 | |

we obtained a favorable Constant score (81.14±6.11). In our radiological evaluation at the end of the first year (1), we found a statistically significant increase in the supraspinatus and subscapularis muscle volumes ($p < 0.05$). (2) In particular, there was no statistically significant difference in the preoperative - postoperative supraspinatus volumes of the patients with grade 2 fatty degeneration, while there was a significant difference in their subscapularis volumes ($p < 0.009$). (3) The patients with grade 2 fatty degeneration had a better Constant score.

Rotator cuff muscles function in perfect harmony with each other. They provide combined dynamic stabilization in many shoulder movements [15]. Because of this harmony, injury to any of these muscles causes the others to be affected [8, 16]. The strongest and largest one among the rotator cuff muscles is the subscapularis muscle. Therefore, the subscapularis muscle is very likely to be affected by possible rotator cuff injuries [17]. In chronic degenerated isolated supraspinatus tears, the subscapularis tendon is loaded more heavily, leading to changes in its structure [18]. Based on this information, we investigated the changes in the supraspinatus and subscapularis volumes with preoperative MRI and in the 1st year after the successful repair, and the correlation of these changes with functional results in cases of isolated supraspinatus tears. The correlation analysis revealed that the subscapularis volumes increased significantly in the first year after successful supraspinatus repairs and there was a positive correlation between the postoperative subscapularis volumes and postoperative supraspinatus volume ($p = 0.004$; $r = 0.601$) (Figure 1). Based on these results, we think that the change in the subscapularis volume can be used as a radiological evaluation criterion after successful supraspinatus repair.

The MRI is excellent for evaluating the ligament structures and rotator cuff around the joint [11, 19]. However, there is no clear parameter defined for the radiological evaluation of success after rotator cuff repair [9, 10]. A reliable radiological parameter is important in predicting results after repair.

Studies have reported conflicting results about the recovery status of atrophy in the supraspinatus muscle after rotator cuff repair. Although some of the authors have reported successful clinical results after the repair, some have reported that atrophy does not improve and is irreversible [20, 21]. Some other authors have reported that atrophy and fat infiltration are improved after successful rotator cuff repair [7, 22]. In our study, we found an increase in analysis of both muscle volumes in grade 1 patients and only in the analysis of the subscapularis muscle volume in grade 2 patients, which was statistically significant ($p < 0.05$). However, we could find no statistical significance in grade 3 patients, though there was an increase in their muscle volumes. Our study demonstrates that there is an increase in muscle volumes after successful repair of isolated small and medium-size supraspinatus tears, and good Constant scores can be obtained in parallel with the increase in muscle volume in these patients.

Chung [23] et al. examined the supraspinatus muscle volume after rotator cuff repair. They reported that a supraspinatus muscle volume on MRIs obtained in the early postoperative period was increased compared to the preoperative volumes and therefore, the supraspinatus volumes measured in the preoperative MRI evaluation might be misleading. They reported that postoperative scan should be done immediately with MRI and subsequent evaluations should be made by taking this MRI into consideration in order to better evaluate the radiological success after repair. We evaluated our patients with MRI at the end of the first year. Radiologically, we evaluated the supraspinatus and subscapularis volumes. No significant difference was observed in the preoperative - postoperative supraspinatus volumes of the patients with grade 2 fatty degeneration. However, we found statistical significance in the preoperative - postoperative subscapularis evaluation ($p < 0.009$). Postoperative early MRI is not preferred because it brings additional costs and is often not necessary. Considering our results, we think that it is appropriate to use subscapularis as a criterion of success when evaluating patients radiologically. Chung et al. already showed us that the supraspinatus muscle volume was measured to be greater compared to the preoperative volumes when the radiological examination was performed immediately after repair [23]. This study shows that preoperative supraspinatus volumes may not be measured accurately. Although many authors have reported successful results, they reported that atrophy of the supraspinatus muscle did not improve [20, 21]. Thus, it can be concluded that the evaluation of the supraspinatus muscle volume can be variable and is not correlated with functional results. In the study by Hata et al. examining [8] 23 patients with isolated supraspinatus tear, the supraspinatus and infraspinatus muscle volumes were examined. They reported that there was atrophy in the infraspinatus muscle even if the infraspinatus tendon was intact in cases of supraspinatus tears, and atrophy improved with the repair of the supraspinatus muscle. Therefore, they included the infraspinatus muscle in the evaluation. On MRI evaluation at the 6th month, they reported that there was no improvement in the supraspinatus muscle, but the volume of the infraspinatus muscle increased. We think that it will be appropriate to make evaluation with a muscle that is a part of the cuff and has a different insertion (the subscapularis muscle) rather than with the supraspinatus and infraspinatus muscles alone in order to elucidate these contradictions in the literature and to make better conclusions for MRI evaluation. According to our results, we think that measuring the volume of the subscapularis muscle is a reliable radiological criterion for evaluating success and recovery.

The most important limitation of this study was the small number of patients. The retrospective design of the study may be another limitation. Prospective randomized studies including higher number of patients are needed for better results.

### *Conclusion*

The postoperative volume values were increased in the follow-up in all patients after isolated supraspinatus tears. In the patients with grade 1 and 2 fatty degeneration, the increases in the supraspinatus and subscapularis muscle volumes were significant after repair and were correlated with each other. Therefore, the subscapularis muscle volume is a reliable parameter in determining success in the radiological evaluation of isolated supraspinatus tears.

***Scientific Responsibility Statement***

*The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.*

***Animal and human rights statement***

*All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.*

***Funding:*** *None*

***Conflict of interest***

*None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.*

***References***

*1. Gül O, Okutan AE, Ayas MS. Arthroscopic glenoid labral lesion repair using all-suture anchor for traumatic anterior shoulder instability: short-term results. J shoulder Elb Surg. 2019; 28:1991–7. DOI:10.1016/j.jse.2019.03.003.*

*2. Klouche S, Lefevre N, Herman S, Gerometta A, Bohu Y. . Return to Sport After Rotator Cuff Tear Repair: A Systematic Review and Meta-Analysis. Am J Sports Med. 2016; DOI:10.1177/0363546515598995.*

*3. Adams CR, Brady PC, Koo SS, Narbona P, Arrigoni P, Karnes GJ, et al.A systematic approach for diagnosing subscapularis tendon tears with preoperative magnetic resonance imaging scans. Arthroscopy. 2012; 28(11):1592–600. DOI:10.1016/j.arthro.2012.04.142.*

*4. Wieser K, Joshy J, Filli L, Kriechling P, Sutter R, Fürnstahl P, et al. Changes of Supraspinatus Muscle Volume and Fat Fraction After Successful or Failed Arthroscopic Rotator Cuff Repair. Am J Sports Med. 2019; 47(13):3080–88. DOI:10.1177/0363546519876289.*

*5. Lhee SH, Singh AK, Lee DY. Does magnetic resonance imaging appearance of supraspinatus muscle atrophy change after repairing rotator cuff tears? J Shoulder Elb Surg. 2017; 26(3):416–23. DOI:10.1016/j.jse.2016.09.044.*

*6. Kim YK, Choi ES, Kim KT, Yoon JR, Chae SH. . Quantitative measurement of muscle atrophy and fat infiltration of the supraspinatus muscle using ultrasonography after arthroscopic rotator cuff repair. Ann Rehabil Med. 2018; 42:260–9. DOI:10.5535/arm.2018.42.2.260.*

*7. Thomazeau H, Boukobza E, Morcet N, Chaperon J, Langlais F.. Prediction of rotator cuff repair results by magnetic resonance imaging. Clin Orthop Relat Res. 1997; 344:275–83. DOI:10.1097/00003086-199711000-00027.*

*8. Hata Y, Saitoh S, Murakami N, Kobayashi H, Kaito T, Kato H.. Volume changes of supraspinatus and infraspinatus muscles after supraspinatus tendon repair: a magnetic resonance imaging study. J Shoulder Elb Surg. 2005; 14(6):631–5. DOI:10.1016/j.jse.2005.03.012.*

*9. Iannotti JP, Zlatkin MB, Esterhai JL, Kressel HY, Dalinka MK, Spindler KP.. Magnetic resonance imaging of the shoulder. Sensitivity, specificity, and predictive value. J Bone Joint Surg Am. 1991; 73(1):17–29.*

*10. Zanetti M, Gerber C, Hodler J. Quantitative assessment of the muscles of the rotator cuff with magnetic resonance imaging. Invest Radiol. 1998; 33(3):163–70. DOI:10.1097/00004424-199803000-00006.*

*11. Tingart MJ, Apreleva M, Lehtinen JT, Capell B, Palmer WE, Warner JJP.. Magnetic Resonance Imaging in Quantitative Analysis of Rotator Cuff Muscle Volume. Clin Orthop Relat Res. 2003; 415:104–10. DOI:10.1097/01.blo.0000092969.12414.e1.*

*12. DeOrio JK, Cofield RH. Results of a second attempt at surgical repair of a failed initial rotator-cuff repair. J Bone Joint Surg Am. 1984. 66(4):563–7. DOI:10.2106/00004623-198466040-00011.*

*13. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures: Pre- and postoperative evaluation by CT scan. Clin Orthop Relat Res. 1994;(304):78–83.*

*14. Lehtinen JT, Tingart MJ, Apreleva M, Zurakowski D, Palmer W, Warner JJP. . Practical assessment of rotator cuff muscle volumes using shoulder MRI. Acta Orthop Scand. 2003; 76(4):722–9. DOI:10.1080/00016470310018270.*

*15. Lugo R, Kung P, Ma CB. Shoulder biomechanics. Eur J Radiol. 2008;68(1):16–24. DOI:10.1016/j.ejrad.2008.02.051*

*16. Carbone S, Gumina S. Rotator cuff biomechanics. In: Gumina S, editor. Rotator Cuff Tear: Pathogenesis, Evaluation and Treatment. Springer, Cham; 2016.p.45–51*

*17. Gausden EB, McCarthy MM, Kontaxis A, Corpus KT, Gulotta LW, Kelly AM.. Subscapularis tendon loading during activities of daily living. J Shoulder Elb Surg. 2017; 26(2):331–6. DOI:10.1016/j.jse.2016.07.013.*

*18. Bergin D, Parker L, Zoga A, Morrison W. Abnormalities on MRI of the subscapularis tendon in the presence of a full-thickness supraspinatus tendon tear. Am J Roentgenol. 2006; 186(2):454–9. DOI:10.2214/AJR.04.1723.*

*19. Ozturk R, Karakoc Y. Arthroscopic Treatment of Benign Tumors and Tumor-Like Lesions Located in and Around the Knee Joint. ULUTAS Med J. 2018; 4(1):19. DOI:10.5455/umj.20181112082014.*

*20. Deniz G, Kose O, Tugay A, Guler F, Turan A. Fatty degeneration and atrophy of the rotator cuff muscles after arthroscopic repair: Does it improve, halt or*

*deteriorate? Arch Orthop Trauma Surg. 2014; 134(7):985–90. DOI:10.1007/s00402-014-2009-5.*
*21. Gladstone JN, Bishop JY, Lo IKY, Flatow EL. Fatty Infiltration and Atrophy of the Rotator Cuff do not Improve after Rotator Cuff Repair and Correlate with Poor Functional Outcome. Am J Sports Med. 2007; 35(5):719–28. DOI:10.1177/0363546506297539.*
*22. Chung SW, Kim SH, Tae SK, Yoon JP, Choi JA, Oh JH. Is the supraspinatus muscle atrophy truly irreversible after surgical repair of rotator cuff tears? Clin Orthop Surg. 2013; 5(1):55–65. DOI:10.4055/cios.2013.5.1.55.*
*23. Chung SW, Oh K-S, Moon SG, Kim NR, Lee JW, Shim E, et al. Serial Changes in 3-Dimensional Supraspinatus Muscle Volume After Rotator Cuff Repair. Am J Sports Med. 2017; 45(10):2345–54. DOI:10.1177/0363546517706699.*

***How to cite this article:***
*Kerim Öner, Muhammet Salih Ayas, Mehtap Oktay. Subscapularis volume analysis as a radiological criterion for evaluating success after arthroscopic repair of supraspinatus tears. Ann Clin Anal Med 2021;12(3):302-307*